C E R A M I C S   P R O C E S S   S Y S T E M S   C O R P O R A T I O N

AlSiC+In-Situ Pyrolytic Graphite

Extremely High Thermal Conductivity Package Components for High Heat Flux Semiconductors, RF/Wireless, and Optoelectronics

CPS designs and manufactures aluminum-silicon-carbide (AlSiC) metal matrix composite components utilized as lids, substrates, and other package components where a CTE-matched, high-strength, lightweight material is needed. The CPS QuickCast™ net-shape casting process provides a unique manufacturing method that eliminates all or most machining requirements for typical package component features. This combination of excellent AlSiC material attributes and a precision, high-volume, net-shape casting process has established CPS as a qualified, reliable vendor to major IC, RF, and power semiconductor manufacturers worldwide.

These AlSiC components have an excellent thermal conductivity value (isotropic) of 180W/m°K. AlSiC components have therefore found acceptance wherever in-plane heat spreading as well as excellent through-body heat transfer is required.

Extremely high thermal conductivity materials (values greater than 1000W/m°K) can now be inserted and captured within AlSiC components. The CPS QuickCast net-shape process also makes possible the in-situ capture of a variety of other material types within an AlSiC component. No other metal matrix composite vendor utilizes such an advanced manufacturing process and CPS therefore has established a leading-edge position as a supplier of practical and cost-effective package components that enables:

- CTE-matching of lid component to substrate or die
- Insertion of extremely high thermal conductivity materials:
  - ✓ X-Y direction: In-plane relative to component base surface
  - ✓ Z direction: Perpendicular to plane of structure base surface

An additional benefit of the QuickCast process, especially important for current optoelectronic module substrate design requirements, is the ability to manufacture substrates that also can be enabled with:

- Low thermal conductivity zones in-plane, to serve as:
  - ✓ Heat flow barriers for optoelectronic substrates
  - ✓ Thermal isolation for temperature-sensitive components

Table 1. High-Conductivity In-Situ Material Options

Highly-Oriented Pyrolytic Graphite (HOPG):

- X-Y thermal conductivity: 1350 W/mK[1]
- Z-direction thermal conductivity: 10 W/mK
- Excellent heat spreading characteristics
- Relatively inexpensive
- Production applications in avionics, commercial RF, and mil package components.

CVD Diamond:

- Isotropic thermal conductivity: 1200 W/mK[2]
- Excellent heat spreading characteristics
- Relatively inexpensive
- Exposed surface metallization for direct die attachment for maximum hot spot spreading
- Excellent solution for SiC, GaAs, SiN die substrates
- Contact CPS for additional information about CVD diamond inserts in AlSiC structures.

NOTES:

1. Minimum thermal conductivity value, X-Y, warranted by vendor; typical value: 1550 W/mK.
2. Thermal conductivity value for selected grade of CVD diamond.

Maximum Performance and Low Cost, Proven Advantages

CPS developed the QuickCast process as the most effective, lowest-cost manufacturing method for advanced metal matrix composites. This unique process enables complex shapes and structures to be cast in a two-step casting system that was designed to provide these product attributes:

- *Net-shape (zero shrinkage) component and feature footprint*
- *High-volume production capacity typical of standard die casting runs*
- *Hermetic, non-sintered, non-porous components*
- *Flexible composite matrix formulations*
- *Uniform aluminum skin on all as-cast surfaces, enabling the use of standard plating techniques and plating metals*
- *Low cost, high-volume net-shape component pricing competitive with machined CuMo, CuW packaging materials*
- *Precision casting of very tight tolerance and flatness requirements (see next page for specific tolerance and flatness data)*

For additional Information, contact CPS. Website: www.alsic.com

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- *Aluminum prototype tools for prototyping and small lot production*
- *Multi-cavity steel production tools for maximum through-put, minimum cost.*

Designing with Highly-Oriented Pyrolytic Graphite (HOPG) in AlSiC Structures

CPS can utilize one or more wafers of HOPG captured in an AlSiC component in several ways, determined by which direction is most valuable for maximum heat flow within the AlSiC component. AlSiC packaging components are typically custom designs; these components are relatively inexpensive and are practical solutions to today's high-heat flux packaging requirements. Insert materials including CVD diamond in several grades can also be used; contact CPS for further information.

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Principal categories of in-situ HOPG applications are:

Type 1. In-plane HOPG wafer insertion to maximize X-Y thermal conductivity for maximum heat spreading from a semiconductor die, laser diode, or other high-power density component mounted on the AlSiC substrate or package component.

Type 2. Perpendicular insertion of one or more HOPG wafers to maximize Z-direction thermal conductivity, for maximum heat transfer through an AlSiC component from the die or other heat source to an attached heat sink, cold plate, heat pipe, or other thermal solution.

Design considerations for application type 1:

The use of HOPG wafers or tiles is limited to internal capture with no exposed graphite surfaces. The HOPG wafer is fragile and not recommended for use with an exposed surface.

CPS's proprietary QuickSet™ and QuickCast™ composite casting processes mechanically lock the high-conductivity insert material within the component metal matrix. All CPS AlSiC components are typically hermetic and any hermeticity and cosmetic requirement should be specified during the design stage. The CPS manufacturing processes yield net-shape components with little or no post-processing machining; typical casting tolerances and flatnesses are equal to or better than that of traditional aluminum die-casting practices. Tolerances for pockets, pedestals, sidewall features, through-holes or ferrule locations, and exterior or interior flatness typically should be specified; the CPS manufacturing processes allow for great flexibility in the location of such features. The physical dimensions, including thickness of HOPG wafer(s) to be captured in-situ will be determined by thermal modeling and/or joint development with a customer to determine the maximum thermal performance enhancement needed, in combination with evaluation of component cost. General guidelines are listed in Table 2, below.

A typical example of the use of an HOPG insert in an AlSiC component is for a lid component that will be CTE-matched to a BGA substrate or to an optoelectronics module substrate (such as Kyocera's high-CTE LTCC materials). For an ASIC or server processor lid measuring 42mm x 42mm, an HOPG insert of 25mm x 25mm is typical; the thickness of this HOPG wafer may be 0.015".

Design considerations for application type 2:

All of the above statements regarding in-situ capture of an HOPG wafer, with no exposed surfaces, and information regarding the casting processes applies to application type 2, also. Thermal modeling using CFD tools has demonstrated that the use of highly-oriented pyrolytic graphite inserted into an AlSiC structure can yield an overall thermal conductivity value equivalent to that of copper. The value to the package and thermal engineer of this concept is:

1. CTE-matched AlSiC lid or component, to the value of a substrate or die material.
2. Significant weight reduction for a completed assembly; AlSiC has a density of approximately 3.0g/cm^3 versus 8.9g/cm^3 for copper.
3. Ability to plate finished component with Ni/Au, electroless nickel, and other standard plating processes typically used for aluminum.
4. Hermeticity for completed AlSiC component for all non-machined areas.
5. Ability to braze convoluted fin packs and other heat sink structures to the exterior surface of any CPS AlSiC component, after plating.
6. High-strength and high Young's modulus values for all AlSiC components.

Table 2. Designing AlSiC+ In-Situ HOPG

HOPG Physical Dimensions:

- Minimum footprint: 0.50" x 0.50"
- Maximum footprint: 6.00" x 10.00" [3]
- HOPG thickness: 0.015 - 0.025" [3, 4]

HOPG In-Situ Placement:

- Separation spacing for multiple wafer inserts: 0.020" (minimum)[4]

NOTES:

3. Suggested dimensional minimums and maximums.
4. Typical

Table 3. Comparative properties for CPS AlSiC metal matrix composite structures and insert materials

	AlSiC-9	AlSiC-12	HOPG Insert
Thermal Conductivity	180W/m°K (isotropic)	180W/m°K (isotropic)	1350W/m°K(κ_{XY}) 10 (κ_Z)
Density	3.0 g/cm^3	3.0 g/cm^3	2.6 g/cm^3
Technical CTE (30 – 200°C)	8.7 ppm/°C	11.7 ppm/°C	-1.0 ppm/°C (XY axis)
Young's Modulus:	192 GPa	167 GPa	--